Section V - Plan Formulation

1. Rationale and Constraints

The plan formulation rationale is to identify and evaluate a range of alternatives that will satisfy fully or partially the problems, needs, opportunities and study objectives discussed in Section IV. Plan formulation for this study has focused on alternatives to improve waterway transportation insofar as the U. S. Army Corps of Engineers or the Tennessee Valley Authority has developmental authority. Other resource problems, needs, and opportunities, such as recreational boating and fish and wildlife enhancement, have been addressed in the overall context of potential navigation improvements.

The planning and development of water resource improvements follow guidance given in current policies and regulations. Principles and Guidelines has two major guidelines: 1) the recommended plan must have incremental system benefits (transportation savings) in excess of incremental system costs, and 2) the recommended plan should provide the maximum net economic benefits to the nation (NED Plan). The NED Plan must be selected unless there are overriding reasons to select another plan. In addition, the Water Resources Development Act of 1986 (Public Law 99-662) requires that one-half of the construction cost of inland navigation projects be paid from the Inland Waterways Trust Fund. Therefore, a recommended plan must also be acceptable to the navigation industry as represented by the Inland Waterway User's Board.

The study is being conducted under several constraints. Since the study was initiated, as a work for others effort, the Corps and TVA agreed to utilize existing TVA design and cost data as the basis for this study. Therefore, only limited design work was accomplished to adjust design drawings and check quantities. Two other constraints were limited funding and time available to complete the study. Because of limited funding, additional geotechnical investigations normally conducted by the Corps at this level of study were not accomplished. In addition, innovative design studies are not conducted and will be delayed until a later stage of design. Since closure of the lock in the future due to safety concerns is inevitable and near-term closure is a possibility due to uncertainty in the evaluation methods and indeterminacy in the structural behavior, the time available for the feasibility study, project authorization process, project design and construction, time available is limited.

2. Rationale for Continued Operation

Current policy requires presentation of the rationale for continuing operation of the existing project. Benefits associated with Chickamauga Lock are both national and regional in nature and support continued operation of a lock at Chickamauga.

The importance of the Chickamauga project and the Upper Tennessee River segment to the entire Eastern Tennessee region is evidenced by its 60 years of continuous service. The dollar benefits to the national economy of the low cost transportation afforded by the Upper Tennessee projects are estimated to be over $18 million annually. These benefits exceed the costs of measures designed to prolong the useful life of the project. Therefore, continued operation of the Chickamauga Lock is warranted.

In addition to commercial navigation, the Chickamauga Lock, as noted previously, is heavily used by recreational boating traffic. Between 1990 and 1998, the number of recreational vessels handled at the Chickamauga facility averaged 4,613. Benefits associated with the recreational usage of the locks are estimated at $350,000 per annum.

In conjunction with direct navigation benefits, the availability of commercial navigation on the Upper Tennessee has important direct and indirect impacts on the regional economy. Companies have been attracted to the East Tennessee region because of the availability of waterway transportation. Important company expansions in the area have been linked to the availability of waterway transportation. A shutdown of Chickamauga Lock would increase the transportation bill for current waterway-using companies that continue to operate under a closed lock option.

Waterway transportation has enabled the Department of Energy to carry on certain aspects of its defense-related work at Oak Ridge. DOE officials have pointed out that a shutdown of the Chickamauga facility would prevent the agency from considering or undertaking certain defense-related work at the Oak Ridge facility.

The most visible effect of a cessation of navigation on the Upper Tennessee would be the complete shutdown of some waterway-using companies. If the Chickamauga lock were to close, two companies accounting for over 500 jobs would close permanently. The impacts include the direct and indirect employment and income effects of the company shutdowns. The direct effects are the employment and income losses at the companies themselves. The indirect effects are the losses that result when the lost income is no longer circulating in the local and regional economies.

Permanent closure of the lock in year 2010 would result in the loss of an estimated 836 jobs, including 517 direct and 319 indirect employment losses. The total earnings loss would be about $44 million, which includes $26 million in direct losses and $18 million in indirect losses. With normal growth, the impact of a closure in 2020 would be the loss of an estimated 1,377 total jobs and $51 million in total earnings. It is important to note that the earnings loss to the local and regional economies is an annual loss. The annual losses between 2010 and 2020, when discounted at a rate of 6.375 percent, have an accumulated present value of about $617 million. Although these company closures would have only a small impact relative to the economy of the 70-county study area, the local county-level impact would be considerably larger.

3. Without-project Condition

a. General. The without-project condition (WOPC) is the future condition deemed most likely to prevail in the absence of any proposed project requiring additional congressional authorization or any change in existing law or public policy. The WOPC is selected from a set of possible alternative without-project futures.

Formulation of the WOPC begins with the existing locks, their current performance and their structural condition. On inland navigation studies such as this, where a Federal project currently exists, the existing project can be included as an element of the without-project condition if it is economically justified. Any reasonably expected and economically justified nonstructural practices within the Corps of Engineers' discretion are to be assumed implemented at the appropriate time. Operational alternatives (the use of helper boats and revised lockage policies) and maintenance alternatives are examined for their ability to improve project performance, insuring the best use of the existing facilities in the without-project future. However, nonstructural options do not address the structural reliability (AAR) problems at the project and thus do not extend project life.

Current guidance requires that major features of the WOPC be economically justified with respect to a baseline condition that assumes that major components of the existing facility will be repaired only as they fail (reach unsatisfactory performance), the so-called "fix-as-fail" scenario. This was the starting point for the Chickamauga analysis. Under the "fix-as-fail" scenario, normal maintenance would continue as presently scheduled, however, preventative maintenance would not be undertaken. Under this scenario, the project would eventually shut down because of continuous degradation or dam safety issues.

Other WOPC scenarios considered are advance maintenance of major components, replacement of major components and a complete replacement-in-kind (RIK) of the existing lock. In an advance maintenance scenario, it is assumed that additional funds will be available to extend the life of the structure by increasing maintenance. This, of course, comes at the cost of not only the increased maintenance, but also of substantially more and longer closures as the project ages. With advance maintenance, the project might still eventually shut down, but the shutdown would be later than in the baseline condition.

Both TVA and Corps engineers agree that major component replacement by itself (termed major rehabilitation) is not practical for the Chickamauga project since the underlying problem of concrete growth would still exist. While it is feasible to replace the miter gates, operating machinery, and some of the other lock components, doing so will not appreciably extend the useful life of the project because of the AAR problems.

To respond to the major concerns associated with AAR and the uncontrolled flow of water through the monoliths, the lock wall monoliths would have to be replaced. This is the same as building a new lock, however, the old one would have to be removed first. This effort would therefore result in significantly greater costs both in construction costs and to the waterway using industries.

Dewatering durations (requiring lock closures) would be long enough (180-days or longer) to drive movements permanently off the water to more costly overland transportation. Some companies would go out of business. Advance maintenance appears to be a more efficient way to extend the life of the project without sacrificing significant decreased project reliability.

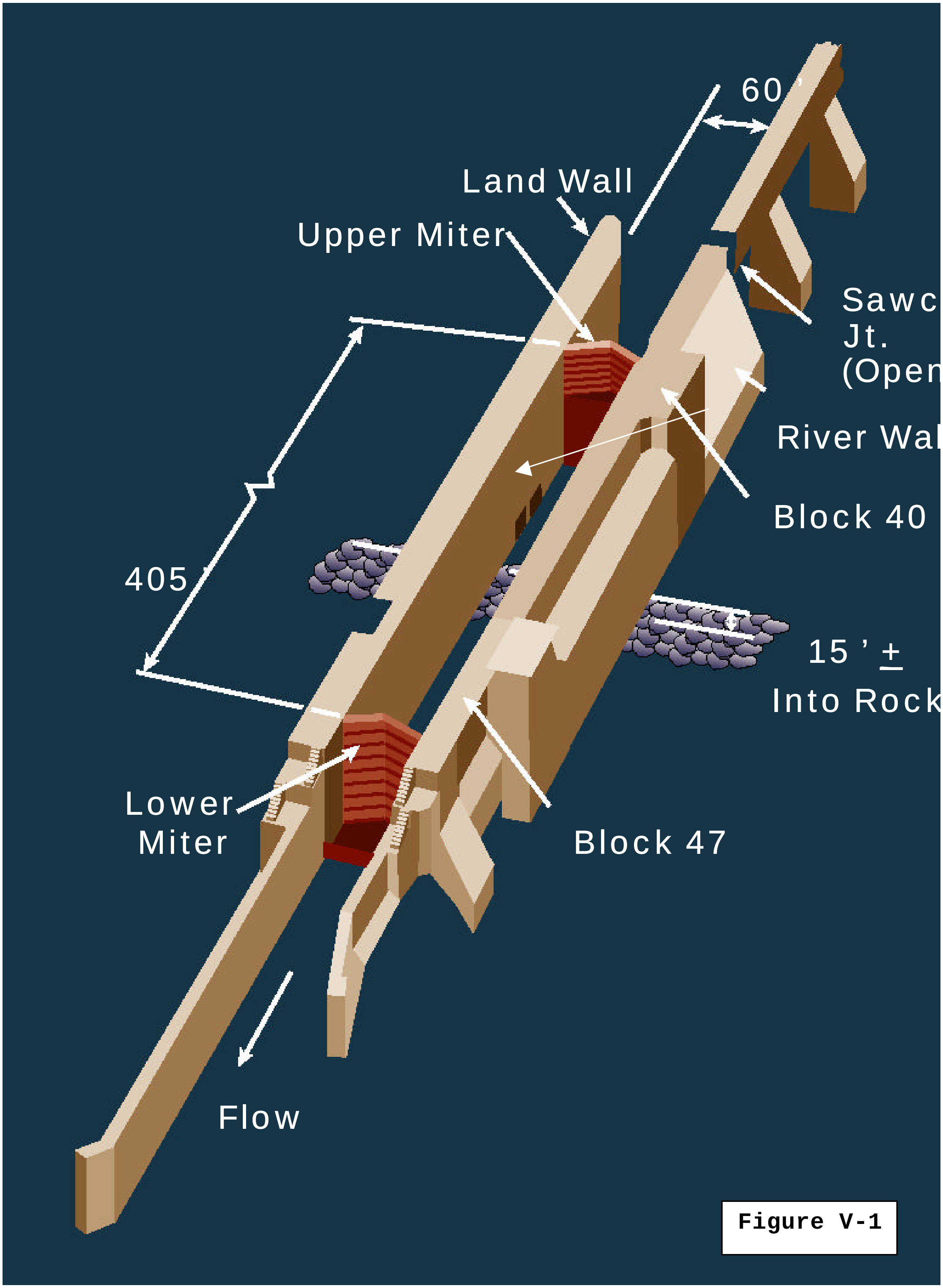
Finally, with RIK, a new lock chamber identical in size to the existing lock chamber would be built riverward of the existing chamber and just downstream of the dam. This alternative would greatly reduce, if not eliminate, the existing concrete growth problem at the lock, while extending the life of the project indefinitely. With RIK, the old lock would be decommissioned and plugged with concrete creating a permanent water barrier.

b. Project Reliability. Concern over the reliability of the Chickamauga project stems primarily from the concrete growth (AAR) and the associated structural deterioration and misalignment. In addition, reliability issues due to simple age and usage of the facility are a concern. At 61 years, the Chickamauga project is now the oldest main lock on the Tennessee River. The high number of lock operation cycles has a significant impact on the reliability of lock components, even if there were no AAR problems.

Overall project reliability is a function of the performance of the individual components at the project. The critical components are those whose unacceptable performance would cause an interruption in lock service. Some of the components are easily evaluated through standard engineering reliability analysis, while other components are less critical to the lock performance or are not easily evaluated through standard engineering studies. For those later components, it is assumed that they are kept operational through a maintenance program. Based on a site inspection and information provided by both project and Nashville District maintenance staff, it was determined that five key components would be analyzed as part of the engineering reliability analyses. These components were deemed key to lock performance and most likely to be impacted either by the AAR or age. These five components are (1) the lower riverward miter gate monolith (Block 47) (AAR related), (2) miter gates (age related), (3) lock chamber river wall monoliths (block 40)(AAR related) and (4) rock anchors installed in 1996 (AAR related). Figure V-1 shows the location of the various components (except for the rock anchors that have been installed in both lock walls and the upper sill) included in the reliability analysis.

(1) Monolith Block 47. The lower, riverward miter gate monolith is commonly called Block 47. This monolith is critical to the safe operation of the project. Not only does it distribute the loads from the lower miter gates when upper pool is in the chamber, but it also forms part of the continuous water barrier that separates upper and lower pools. This component is considered the most critical because of the aforementioned reasons, as well as the condition of the structure. Block 47 has cracking damage through its cross-section at several locations, and the top of the block has moved several inches upward and downstream due to concrete expansion over the years. The miter gates are anchored to the top section of this monolith, and substantial adjustments, including rebuilding the gudgeon pin connection, have been required over the years to keep the miter gates in alignment. There is significant concern regarding the potential for the concrete to fail around the embedded miter gate anchorage. Failure of the anchorage would likely result in the miter gate falling. This concrete must be sound for the continued safe function of the miter gates. Misalignment of the miter gates caused in part by the expansion of the concrete can induce additional stress in the gates leading to accelerated fatigue cracking.

(2) Miter Gates. The lower miter gates at Chickamauga are arched and riveted. Although there have been no known structural problems, these miter gates are old and well used and warrant concern within the study period. The lower miter gates were investigated using reliability methods. The gates are redundant enough that single cracks do not constitute overall gate failure, however, as the cracks grow over a period of years, they will stretch between adjacent rivet holes. It is at this point that concern of the overall gate becomes an issue.


60 '
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Miter
Block 47
Flow

Figure V-1

The upper miter gates are not arched, but they are riveted. These gates were analyzed in the same manner as the lower gates. Cracking of the gates due to excessive use was also the major concern for these gates.

(3) Lock Chamber River Wall Monoliths (Block 40). Block 47 is the most critical monolith due to its excessive deterioration and importance for supporting the miter gate. However, all monoliths at Chickamauga are experiencing serious structural problems associated with AAR. They experience different levels of damage according to their geometry, restraint, and other factors. The river lock wall monoliths have deteriorated to a greater extent than the land wall monoliths, most likely because the land wall is restrained by the earth fill behind it. The monolith selected to represent the river wall is referred to as Block 40, which is near the centerline of the lock.

(4) Rock Anchors Installed in 1996. Post-tensioned tendons were installed throughout the lock wall monoliths in 1996-97. This was done to provide additional stability resistance to overturning and sliding of the monoliths. Detailed engineering analyses associated with Block 47 and Block 40 revealed the importance of the tendons in providing structural restraint against the concrete expansion. The dewatering inspection of the riverside culvert during the summer of 1999 revealed that the tendons and grout installed in 1996-97 had greatly reduced the leakage through the river wall compared to previous dewaterings. Therefore, the long-term performance of these tendons is a concern to the overall structural integrity of the monoliths. A tendon reliability model was developed to better determine when the rock anchors (tendons) would become ineffective.

(5) Additional Components. During the course of the study, additional components were identified as important to the project analysis (AAR related), but for which reliability models are not developed. These components were the land wall/embankment interface, lock wall compressive stress build-up, and lock concrete surface deterioration. To address these components, expert elicitation was used to develop hazard rates and consequence event trees. The consequences associated with these components had the potential to have a major impact on the analysis but were too costly to be considered as part of an on-going maintenance program.

(6) Other Components in Economic Analysis. Several other structural components are key to the economic analysis, but not addressed specifically in the reliability analysis. The impacts for these components were included in overall cost and closure matrices. Examples of these components are the mechanical and electrical systems, and the guard/guide walls. It is known that items such as the floating mooring bits and mechanical systems have required realignment through the years resulting from the concrete expansion. In addition, cuts through the concrete upper guard wall were required to provide sufficient room for the concrete to “grow” between monoliths. These types of repair costs and closures are captured in the economic analysis through additional maintenance closures and costs as opposed to individual reliability models.

c. Nonstructural Measures Considered. To remedy the structural reliability problem and address capacity problems at Chickamauga, several nonstructural measures were considered that are within the latitude of the operating agency. With respect to the condition problems, advance maintenance above traditional routine maintenance levels was considered. Accomplished alone or in combination with other measures as part of the WOPC, nonstructural measures have the potential to prolong the service life of the project. However, the AAR problems would continue with the lock eventually being closed to traffic.

Enhancements to project capacity can be achieved by implementing specific operating measures. These measures would be implemented with a specific maintenance policy i.e., fix-as-fails or advance maintenance. Operational measures considered included implementation of various lockage service policies (first-in/first-out vs 3-up then 3-down), limitation of tow sizes (3-barges and towboat per tow vs no tow size limit), and the use of helper boats to reduce lock-processing times.

The option of extending the upper and lower approach walls and adding tow haulage units was considered, but rejected as not practical. There is insufficient area, particularly in the upper approach area, for tows to maneuver with the number of barges that would fit along an extended approach wall. Tow haulage units are currently used for both upper and lower approach walls.

(1) Advance Maintenance Alternatives. The fix-as-fails scenario represents the baseline scenario against which all plans are measured in the economic evaluation. Under the fix-as-fails maintenance scenario, repairs are not undertaken until a component fails. Failure is defined as unacceptable performance by a component (i.e. fatigue in a gate reaching a certain level or stress in a monolith reaching certain levels, and not necessarily a total failure (i.e., gate falling or monolith collapsing). Components are allowed to reach unacceptable performance, before repairs are initiated. This caused longer and more costly closures. Cyclical maintenance closures are also more costly and longer because there are no intermittent repairs. Thus, when cyclical maintenance is actually conducted under the fix-as-fails scenario, more problems will be encountered than with the advance maintenance scenario.

For the advance maintenance scenario, scheduled repairs are undertaken before unacceptable performance is reached. This is the current mode of maintenance at Chickamauga. Regardless of maintenance scenario, routine maintenance is required for any lock and dam. For Chickamauga, routine maintenance is considered to be a lock chamber dewatering approximately every five years to make necessary repairs to miter gates, culvert valves, and other structures that are typically submerged (or partially submerged) during normal operations. In addition, there are costs for lock personnel, utilities, and miscellaneous contracts for items such as minor repairs, painting, etc. While this level of maintenance is usually adequate for locks that don’t exhibit serious problems, this level of maintenance and funding would not be adequate to keep Chickamauga operational because of the problems associated with concrete growth. Therefore, an advance maintenance alternative under the WOPC was developed and projected throughout the study period. Advance maintenance was included in the economic analysis through both the reliability analysis and a cost/closure matrix.

(2) Lockage Service Policies. The current lockage service policy at Chickamauga is first-in/first-out (FIFO). This means that the lock serves the vessels (tows) in the order of their arrival. Lockage service policy can have a significant bearing on operating efficiency, however, it was shown in capacity studies conducted in 1989 and 1993 for Chickamauga, that lockage service policies had

relatively little impact on the efficiency. In the 1993 capacity analyses, the FIFO policy was tested against a three-up/three-down policy. The FIFO policy was found to be marginally more efficient than the three-up/three-down policy. The FIFO lockage service policy was assumed to be in effect under all plans.

(3) Limitation of Tow Sizes. Limitation of tow sizes was considered based on the results of previous capacity studies. It is possible to increase the capacity and operating efficiency of a facility simply by limiting the fleet to a maximum tow size. The 1989 and 1993 capacity studies examined the efficiencies associated with limiting tow sizes at Chickamauga to three, six, and nine (jumbo) barges, and found that limiting tow size to three barges (and thus, three cuts) was the most effective in increasing capacity. The detailed capacity analysis of this alternative presented in the 1993 feasibility study indicated that limiting tow sizes at Chickamauga could increase capacity at the facility by 1.6 million tons. However, further analysis showed that the costs associated with the operation of more and smaller tows overcame the advantage of increased capacity. For that reason, limiting tow sizes was eliminated as a potential nonstructural measure in the without-project condition.

(4) Helper Boats. The helper boat scenarios examined for possible inclusion in the without-project condition would involve use of towboats to assist in pulling unpowered cuts (barges) out of the lock chamber. Helper boats at Chickamauga increase capacity from 8.1 million tons to approximately 11.0 million tons. Helper boat operations are implemented as part of the WOPC when traffic levels are sufficient to economically justify their use. Helper boat procedures are used now on a voluntary basis, when an upbound and a downbound tow arrive at the locks at the same time. Implementation of a helper boat plan would require the use of two 800 hp boats per lock at an annual cost of $1,634,000.

d. Structural Measures Considered. In addition to the nonstructural measures, structural measures were considered that are within the purview of the Corps of Engineers. These include major component replacement and RIK. Major component replacement would involve replacing the identified critical components, either singly or in combination, depending on which approach has the highest net benefits. A RIK would involve construction of a new lock with the same dimensions.

(1) Component Replacement. Major component replacement by itself (termed major rehabilitation) is not practical for the Chickamauga project since the underlying problem of concrete growth would still exist. To respond to the concerns caused by the uncontrolled flow through the monoliths, the lock wall would have to be replaced. This is almost the same, as building a new lock, except, the old lock would have to be removed first. Therefore, replacement of the lock walls would cost more to construct and cost the waterway using industries more from the extended lock closure.

Note that the fix-as-fails and advance maintenance scenarios have replacement of the components as repair options, but that is only a function of the repair due to “unacceptable performance” and not a scheduled individual component replacement program. Component replacement, including bundling replacements in a major rehabilitation, was eliminated from consideration as a WOPC alternative because of high costs.

(2) Replacement-in-Kind. The remaining structural alternative considered under the WOPC is a complete RIK. Under this alternative, the existing 60’x360’ lock would be replaced with one of the same dimensions. The new lock would be riverward of the existing lock and just downstream of the dam. This will allow use of the current lock during construction of the replacement lock. Although the current lock dimensions are not compatible with current equipment sizes (a jumbo barge measures 35’x195’), this is the only lock size that could be constructed without additional congressional authorization. If economically justified, a RIK could be undertaken through the Major Rehabilitation Program. This alternative would alleviate industry concerns about the project’s structural problems (poor reliability) however; it would not take advantage of the opportunity to improve the economic efficiency of the facility. Industry sources have indicated that concern over the poor reliability alone has inhibited their utilization of the waterway. It is estimated that RIK could be accomplished at a first cost of $218.6 million.

e. Evaluation of the Without-project Alternatives. The economic evaluation of the WOPC alternatives focuses on the plan that minimizes costs and closures due to component failure. The fix-as-fails, advance maintenance and replace-in-kind alternatives are compared to determine which alternative minimizes costs or alternatively, maximizes net benefits.

The planning horizon in the analysis extends from 2000 to 2060. The base year is 2010 (earliest possible completion year for a RIK) and all costs and benefits are compounded/discounted at the Federal discount rate of 6.375 percent. The costs associated with each alternative include construction costs, helper boat costs (when justified and may be included at either Chickamauga or/and Watts Bar), AAR specific maintenance costs, repair costs, external costs, recreation costs, and transportation costs. The costs used to determine the most likely WOPC are incremental to the fix-as-fails baseline condition.

Chickamauga Lock provides more than $18 million in annual transportation savings based on the 1996 base line waterway traffic. Benefits include all reductions in costs associated with a plan when compared to the costs associated with the fix-as-fails baseline condition. Net benefits are the difference between each alternative's incremental costs and benefits.

f. The Need for System Analysis. The interdependence of traffic flows among the individual elements of the Inland Waterway system is ordinarily a major problem in the economic evaluation of a lock-and-dam project. A change in the performance of one lock or channel segment can affect the efficiencies of other components of the system. For example, additional traffic at Chickamauga Lock could conceivably increase delays at other projects and thereby reduce the benefits attributable to the improved Chickamauga Lock. Similarly, other system projects could restrict system traffic flows and prevent the materialization of additional traffic expected from proposed navigation improvements.

Key considerations are the relative volumes of common traffic at system locks and the capacities of the affected facilities. Since nearly all of the 1996 Upper Tennessee traffic was inbound to or outbound from the system, virtually all of the Watts Bar and Fort Loudoun traffic also transited Chickamauga. For Tennessee River projects downstream of Chickamauga, the Chickamauga traffic made up a sizeable portion of total traffic. However, existing and future levels of excess capacity at the downstream facilities make it unlikely that changes at Chickamauga would produce adverse impacts. Similarly, although no current Chickamauga traffic uses the Tennessee-Tombigbee waterway, future usage of the waterway is anticipated, and excess capacity on the Tennessee-Tombigbee makes it unlikely that changes at Chickamauga could produce adverse system impacts. At Ohio River projects, Chickamauga traffic makes up a very small portion of total traffic levels and the traffic pattern is such that adverse impacts, either of Chickamauga on those projects or those projects on Chickamauga, are unlikely.

Examination of the existing and expected future patterns for Chickamauga traffic, along with an analysis of model results from previous studies, led to a conclusion that a complete navigation system analysis involving the Ohio River System or other broad-ranging system definition was unnecessary. Most of the effects from changes at the Chickamauga facility are expected on the Upper Tennessee itself. In fact, a large majority of the impacts from any proposed changes to the Chickamauga facility would be confined to Chickamauga and Watts Bar. For this reason, the system defined for navigation system modeling was confined to those two locks.

g. Economic Models Used in the Analysis. The primary analytical tools used in this study are the Spreadsheet Equilibrium Traffic (SET) Model; the Chickamauga Waterway Analysis Model (ChickWAM); and the Life Cycle Component Model (LCCM). The SET Model is an EXCEL workbook model used to evaluate and extract rate-savings-eroded movements from a traffic forecast file, thus generating an equilibrium traffic forecast file from which closure diversions and shipping costs are determined by the ChickWAM. The SET was developed specifically for the Chickamauga study.

The ChickWAM is a modification and extension of the Waterway Analysis Model (WAM). The WAM is a stochastic simulation model developed initially by CACI, Incorporated. Extensive modifications to the WAM have been made over a number of years by the Corps of Engineers. The model is used primarily to simulate the impact of tow movements on the inland navigation system. In the current study, the "system" was defined as a two-lock system made up of Chickamauga and Watts Bar. The model simulates the movement-by-movement, cut-by-cut progress of each vessel on the river. In the past, the WAM was used to estimate tonnage-delay relationships at locks. For purposes of the current study, the WAM was modified (ChickWAM) to also accumulate waterway transportation costs and to generate pertinent data such as traffic accommodated, traffic diverted, traffic delays, and rate savings.

The ChickWAM consists of three basic units: model configuration, simulation and statistics compilation. Model configuration defines the system analyzed in terms of the network description, the barges and towboats to be used in the simulation, the shipment list and a list of downtime events. The simulation module processes the input data and moves the shipments from origin to destination through the system elements.

The LCCM is a spreadsheet version of the Life Cycle Lock Model (LCLM) developed by the Corps of Engineers Pittsburgh District. The LCCM is used to process event trees from the engineering reliability analysis and calculate expected values of unsatisfactory performance, given alternative repair, maintenance, rehabilitation or other actions at a lock. The LCCM combines output from the ChickWAM with data generated in the engineering reliability analysis. ChickWAM output becomes the "cost to industry" or benefits forgone from unsatisfactory performance (i.e., lock unreliability). The engineering reliability analysis generates the probabilities of unsatisfactory performance and costs to repair at the facilities.

(1) Average Annual Costs of Alternatives. The average annual costs are divided into two groups, construction costs and non-construction costs. Construction costs are associated with the development of new facilities and pertain only to the RIK. The non-construction costs are further divided into six areas: helper boats, AAR maintenance, repair, external, recreation, and transportation.

Helper boats are used to assist in pulling the unpowered cuts out of the lock chamber. Normally, helper boats are not required at a project until traffic levels start approaching lock capacity. Helper boat operations are implemented at Chickamauga and Watts Bar as part of the without-project condition if or when justified.

AAR maintenance costs are work efforts that are currently scheduled to address AAR related problems.

Repair costs are repairs to the five major lock components subjected to detailed reliability analysis and to the three components evaluated by means of expert elicitation. These values are statistically based and are computed using the LCCM.

In addition to the direct costs associated with transportation and recreation losses from closures and delays at the Chickamauga project, the current study also considered indirect or external costs imposed locally because of waterway traffic diversions. The externalities measured included the cost of delay due to traffic congestion and incidents, pavement damage, truck related accidents, and air pollution. Reductions in these categories of costs that occur with navigation improvements are treated as benefits to implementation of improvements.

Please note that external cost reductions are nonstandard benefits and are undergoing Washington-level review. A final determination regarding the usage of external cost reductions was not received prior to issuance of this report. Tables presenting the analysis without and with the external cost reductions are presented, however, the plans are formulated based on the data with the external cost reductions omitted.

Recreation costs or recreation benefits foregone result primarily from lock closure periods at Chickamauga, when recreational traffic cannot be processed.

Transportation costs are all the costs associated with moving the projected traffic from origin to destination. This includes both overland and waterway modes of transportation.

(a) Fix-as-Fails Alternative Maintenance Scenario. The fix-as-fails scenario assumes a maintenance strategy that reacts to component failure (unacceptable performance) and to AAR maintenance. All component failure and AAR maintenance closures are unscheduled. In the fix-as-fails scenario, helper boats were analyzed but are not economically justified throughout the period of analysis. There are no construction costs assumed in the fix-as-fails scenario. The average annual cost associated with the fix-as-fails scenario is $346.8 million. Table V-1 summarizes the average annual costs associated with the fix-as-fails alternative.

Table V-1 Average Annual Costs, Fix-as-Fails Scenario (Thousands of FY 2001 Dollars, 6.375% Discount Rate)	
Annual Costs	**Fix-as-Fails**
Investment Costs	$0
Non-Construction Costs	
Helper Boats	$0
AAR Maintenance	$3,585
Repair	$1,140
Recreation	$69
Transportation	$342,061
Subtotal, Non-Construction Costs	$346,855
Total Annual Costs	$346,855
Average Annual Costs with Externalities, Fix-as-Fails Scenario	
Investment Costs	$0
Non-Construction Costs	
Helper Boats	$0
AAR Maintenance	$3,585
Repair	$1,140
External	$3,551
Recreation	$69
Transportation	$342,061
Subtotal, Non-Construction Costs	$350,406
Total Annual Costs	$350,406

(b) Advance Maintenance. The advance maintenance scenario assumes a maintenance strategy that reacts before component and/or AAR related failure. All component failure and AAR-maintenance closures are scheduled. In advance maintenance, helper boats were analyzed but are not economically justified throughout the period of analysis. There are no construction costs assumed in the advance maintenance scenario. The average annual cost associated with the advance maintenance scenario is $346.8 million. Table V-2 summarizes the average annual costs associated with the advance maintenance scenario.

Table V-2 Average Annual Costs, Advance Maintenance Scenario
(Thousands of FY 2001 Dollars, 6.375% Discount Rate)

Annual Costs	Advance Maintenance
Investment Costs	$0
Non-Construction Costs	
Helper Boats	$0
AAR Maintenance	$5,199
Repair	$538
Recreation	$56
Transportation	$340,970
Subtotal, Non-Construction Costs	$346,763
Total Annual Costs	$346,763
Average Annual Costs with Externalities, Advance Maintenance Scenario	
Investment Costs	$0
Non-Construction Costs	
Helper Boats	$0
AAR Maintenance	$5,199
Repair	$538
External	$2,329
Recreation	$56
Transportation	$340,970
Subtotal, Non-Construction Costs	$349,092
Total Annual Costs	$349,092

(c) Replacement-in-Kind. The new 60’x360’ lock would be located adjacent to and riverward of the existing lock, requiring the removal of several dam spillway gates and supporting structures. An earliest possible on-line date of 2010 was considered in this replacement-in kind analysis.

The evaluation of a RIK was approached in a manner similar to the fix-as-fails and advance maintenance alternatives for the major lock components. The optimal RIK strategy for the structure, similar to the maintenance strategies, is the strategy that minimizes costs, including the replacement cost. In the RIK, helper boats were analyzed and found feasible at both Chickamauga and Watts Bar. A RIK could be accomplished at a total first cost of $226.4 million. Total average annual costs associated with the RIK (with interest during construction) are $336.1 million. RIK average annual costs are summarized in Table V-3.

Table V-3 Average Annual Costs, Replacement-in-Kind Scenario (Thousands of FY 2001 Dollars, 6.375% Discount Rate)

Annual Costs	RIK
Investment Costs	$17,682
Non-Construction Costs	
Helper Boats	$3,175
Maintenance	$2,601
Repair	$179
Recreation	$27
Transportation	$312,447
Subtotal, Non-Construction Costs	$318,429
Total Annual Costs	$336,111
Average Annual Costs with Externalities, Replacement-in-Kind Scenario	
Investment Costs	$17,682
Non-Construction Costs	
Helper Boats	$3,175
Maintenance	$2,601
Repair	$179
External	$740
Recreation	$27
Transportation	$312,447
Subtotal, Non-Construction Costs	$319,169
Total Annual Costs	$336,851

Engineering reliability analyses were not conducted for the RIK alternative. It was assumed that once the replacement lock was in service, there would be little chance of unsatisfactory performance until the very end of the study period. With present worth discounting, the economic impacts would be negligible. It should be noted that the advance maintenance strategy remains part of the economic analysis until the RIK is complete.

(2) Performance of Alternatives. The following paragraphs compare the performances of the alternative without-project conditions in providing efficient navigation on the Upper Tennessee. The performances are compared in terms of lock capacity, traffic levels accommodated and diverted, and delays that would be realized at Chickamauga and Watts Bar over the planning period. A major assumption in the analysis is that under any of the three options, navigation will remain open, except for repair/maintenance closures during the project study period. This is a conservative assumption, and does not recognize the reality of dam safety issues.

(a) Project Capacities. The Chickamauga and Watts Bar facilities have annual estimated capacities of 7.9 and 8.3 million tons respectively. The fix-as-fails, advance maintenance, and RIK alternatives at Chickamauga are not expected to produce changes in the annual capacity of that facility. However, the expected increase in traffic at a more reliable RIK alternative justifies the use of helper boats at both projects. At Chickamauga, the implementation of helper boat operations would increase the annual capacity by 36 percent to about 11.0 million tons. At Watts Bar, helper boat operations would increase annual capacity by 39 percent, to 11.5 million tons.

(b) Traffic Accommodated. Traffic accommodated at Chickamauga and Watts Bar under Chickamauga’s fix-as-fails, advance maintenance and RIK scenarios are presented in Table V-4. System studies assume the implementation of helper boat operations under each of the without-project alternatives as soon as they are justified. Under the fix-as-fails and advance maintenance scenarios, where helper boats are not justified, system modeling shows that 3.0 million tons of traffic would move through Chickamauga in year 2010, and that this tonnage would increase to 4.4 million tons by 2060. The major constraint to traffic at

Chickamauga under the fix-as-fails and advance maintenance scenarios is risk aversion by shippers to the existing, unreliable Chickamauga facility. Since neither fix-as-fails nor advance maintenance, resolves the AAR problems and its resulting reliability concerns, none of the risk averse traffic utilizes the waterway. Thus, traffic accommodated at Chickamauga and Watts Bar is not affected by capacity constraints in the fix-as-fails and advance maintenance situations.

With a RIK at Chickamauga, the project accommodates 7.5 million tons of traffic in 2010, increasing to 10.1 million tons by 2060. The RIK eliminates project reliability as a concern resulting in the shift of risk-averse traffic to the waterway, but unlike the fix-as-fails and advance maintenance scenarios, capacity constraints at Chickamauga begin to affect traffic levels beginning in 2050.

(c) Traffic Diverted. Table V-5 compares traffic diversions (utilizing overland modes) at Chickamauga and Watts Bar for the alternative without-project condition by year. Traffic diversions to highway form the basis for benefits associated with reductions in highway congestion and emissions under alternative without and with-project conditions. The existing levels of diversions result from the risk-averse behavior of upper Tennessee shippers. Under the fix-as-fails and advance maintenance scenarios, base diversions amount to 5.3 million tons in 2010, and increase to 7.0 million tons in 2060. Under a RIK, diversions are reduced to 0.8 million tons in 2010, and increase to only 1.2 million tons in 2060. A RIK largely eliminates the uncertainty of lock performance, but doesn’t lower waterway costs sufficiently to accommodate all potential Chickamauga demands.

Table V-4 Expected Traffic Accommodated at Chickamauga and Watts Bar Under Alternative Without-project Conditions (Thousand Tons)			
Year/Project	**Total Traffic Demand**	**Fix-as-Fails & Advance Maintenance**	**Replacement-in-Kind**
2000			
Chickamauga	7,586	-	-
Watts Bar	6,530	-	-
2010			
Chickamauga	8,283	2,995	7,485
Watts Bar	7,116	2,236	6,390
2020			
Chickamauga	8,777	3,211	7,917
Watts Bar	7,522	2,380	6,741
2030			
Chickamauga	9,400	3,490	8,461
Watts Bar	8,039	2,572	7,187
2040			
Chickamauga	10,209	3,855	9,168
Watts Bar	8,710	2,823	7,768
2050			
Chickamauga	10,874	4,155	9,746
Watts Bar	9,261	3,028	8,241
2060			
Chickamauga	11,322	4,369	10,133
Watts Bar	9,628	3,174	8,553

Table V-5 Expected Traffic Diversions at Chickamauga and Watts Bar Under Alternative Without-project Condition (Thousand Tons)		
Year/Project	**Fix-as-Fails & Advance Maintenance**	**Replacement-in-Kind**
2010		
Chickamauga	5,288	798
Watts Bar	4,880	726
2020		
Chickamauga	5,566	860
Watts Bar	5,142	781
2030		
Chickamauga	5,910	939
Watts Bar	5,467	852
2040		
Chickamauga	6,354	1,041
Watts Bar	5,887	942
2050		
Chickamauga	6,719	1,128
Watts Bar	6,233	1,020
2060		
Chickamauga	6,953	1,189
Watts Bar	6,454	1,075

(d) Transit Times. Chickamauga Lock's average transit time is composed of a processing and delay time. The small 60'X 360' chamber at Chickamauga made for an average 6.4 lockage-cuts per tow in 1999. This translates into an average processing time of 6.0 hours. Such lengthy processing led to an average 1.5 hours of delay in 1999. The average tow transit time at Chickamauga in 1999 was 7.5 hours (processing time plus delay time).

Expected lock transit-times at Chickamauga under the alternative without-project conditions are shown in Table V-6. Average transit-time at Chickamauga depends on both traffic levels and closures at the facility. Under the fix-as-fails condition, traffic levels are limited by risk aversion on the part of shippers. In this situation, the average transit-time per tow increases from 10.2 hours in

2010 to 13.9 hours in 2060. With a RIK, the risk of a serious structural problem is essentially eliminated, and the risk-averse traffic is attracted to the waterway (traffic accommodated increases). Helper boats are justified at both Chickamauga and Watts Bar when Chickamauga is replaced in-kind. Average tow transit-time at Chickamauga, in this instance increases from 13.7 hours in 2010 to 53.5 hours in 2060.

Table V-6 Expected Transit Times at Chickamauga and Watts Bar Locks Under Alternative Without-project Condition (Hours Per Tow)

Year/Project	Fix-as-Fails & Advance Maintenance	Replacement-in-Kind*
2010		
Chickamauga	10.2	13.7
Watts Bar	8.5	24.6
2020		
Chickamauga	10.7	15.6
Watts Bar	8.7	11.3
2030		
Chickamauga	11.3	18.7
Watts Bar	9.0	12.5
2040		
Chickamauga	12.2	25.7
Watts Bar	9.3	14.4
2050		
Chickamauga	13.1	37.2
Watts Bar	9.6	16.4
2060		
Chickamauga	13.9	53.5
Watts Bar	9.9	18.1

*Processing times increases result from increased traffic at a reliable lock.

(e) Benefit Determination. Table V-7 compares the net incremental annual benefits for the advance maintenance and RIK scenarios as alternative without-project conditions. Benefits are measured as incremental reductions in costs relative to the fix-as-fails scenario (base condition). Incremental annual benefits are comprised of navigation benefits, measured as the change in transportation costs; recreation benefits, measured as the change in recreation costs based on cost per lock closure day; and AAR maintenance benefits, measured as the change in AAR related maintenance costs. Annual benefits (and costs) are computed using a 2000-2060 planning horizon and a 6.375 percent discount rate.

Table V-7 WOPC Summary of Annual Benefits, Costs and Net Benefits (Thousands of FY 2001 Dollars, 6.375% Discount Rate)

Costs/Benefits	Fix-as-Fails	Advance Maintenance	RIK (2010)
Construction Investment Cost	$ 0	$ 0	$ 17,682
Non-Construction Costs:			
Helper Boat	$ 0	$ 0	$ 3,175
Maintenance	3,585	5,199	2,601
Repair	1,140	538	179
Recreation	69	56	27
Transportation	342,061	340,970	312,447
Total Non-Construction Costs	$ 346,855	$ 346,763	$ 318,429
Total Annual Costs	$ 346,855	$ 346,763	$ 336,111
Net Annual Incremental Benefit*	N/A	$ 92	$ 10,744
WOPC Summary of Annual Benefits, Costs (including externalities) and Net Benefits			
Construction Investment Cost	$ 0	$ 0	$ 17,682
Non-Construction Costs:			
Helper Boat	$ 0	$ 0	$ 3,175
Maintenance	3,585	5,199	2,601
Repair	1,140	$538	179
External	3,551	2,329	740
Recreation	69	56	27
Transportation	342,0617	340,970	312,447
Total Non-Construction Costs	$ 350,406	$ 349,092	$ 319,169
Total Annual Costs	$ 350,406	$ 349,092	$ 336,851
Net Annual Incremental Benefit*	N/A	$ 1,314	$ 13,555

*Benefits are costs foregone when compared to the fix-as-fails base condition.

With a RIK, shippers that were formerly risk-averse are attracted to the waterway, since the risk associated with the degraded lock is removed. The levels of recreational benefits are affected greatly by closures at the lock, and with a RIK, closures at the facility are minimized (no AAR related closures), accounting for the higher level of recreational benefits. With a RIK, component repair costs and AAR-related repairs are eliminated after 2010 and only cyclical maintenance requirements and random minor maintenance needs remain.

(3) Timing of Construction Completion for the Replacement-in-Kind. Based on the foregoing analysis of project benefits and a detailed analysis of the associated costs, the RIK was selected as the most probable without-project condition. With annual expected benefits of over $28.4 million and annual costs of $17.7 million, a RIK has the highest level of net benefits, $10.7 million, of any of the without-project alternatives. This analysis assumes an on-line date of 2010 for a new 60’x360’ lock riverward of the existing structure.

The analysis was adjusted to reflect construction completion of the RIK for 2015, 2020, and 2025 by sliding construction costs and the subsequent improved lock performance to the appropriate year while back-filling the analysis (years between 2010 and 2015, 2020, and 2025) with advance maintenance data. The results show discounted construction and helper boat costs and increased repair, maintenance, recreation, and transportation costs. Overall, as shown in Table V-8, a 2010 RIK maximizes expected net benefits.

Table V-8 Replacement-in-Kind Timing Analysis (Thousands of FY 2001 Dollars, 6.375% Discount Rate)				
Costs/Benefits	**Fix-as-Fails**	**RIK 2010**	**RIK 2015**	**RIK 2020**
Construction Investment Cost	$ 0	$ 17,682	$ 12,982	$ 9,531
Non-Construction Costs:				
Helper Boat	$ 0	$ 3,175	$ 2,442	$ 1,752
Maintenance	3,585	2,601	3,072	3,380
Repair	1,140	179	253	317
Recreation	69	27	30	37
Transportation	342,061	312,447	319,775	325,487
Total, Non-Construction Costs	$ 346,855	$ 318,429	$ 325,572	$ 330,973
Total Annual Costs	$ 346,855	$ 336,111	$ 338,554	$ 340,504
Net Annual Incremental Benefit	N/A	$ 10,744	$ 8,301	$ 6,351
Replacement-in-Kind Timing Analysis (Including Externalities)				
Construction Investment Cost	$ 0	$ 17,682	$ 12,982	$ 9,531
Non-Construction Costs:				
Helper Boat	$ 0	$ 3,175	$ 2,442	$ 1,752
Maintenance	3,585	2,601	3,072	3,380
Repair	1,140	179	253	317
External	3,551	740	896	1,036
Recreation	69	27	30	37
Transportation	342,061	312,447	319,775	325,487
Total, Non-Construction Costs	$ 350,406	$ 319,169	$ 326,468	$ 332,009
Total Annual Costs	$ 350,406	$ 336,851	$ 339,450	$ 341,540
Net Annual Incremental Benefit	N/A	$ 13,555	$ 10,956	$ 8,866
*Benefits are costs foregone when compared to the fix-as-fails base condition.				

f. The Selected Without-project Condition. All subsequent incremental navigation impacts and project benefits will be calculated against the without-project condition. Based on the foregoing analysis, the 2010 replacement-in-kind with helper boats at Chickamauga and Watts Bar is selected as the most probable without-project condition. It is more cost effective to replace the lock now and avoid future repair, maintenance and closure costs. A replacement-in-kind would have a first cost of approximately $226.3 million; an incremental annual cost of about $17.7 million and incremental annual benefits of about $28.4 million. With a replacement-in-kind, the project would accommodate 90 percent of projected traffic demands throughout the project economic life, beginning at about 7.5 million tons in 2010 and increasing to about 10.1 million by 2060. Traffic at the Chickamauga facility would likely increase to some extent in anticipation of the completion of a new project over some period prior to the base year. This would increase the pre-base year benefits for a replacement-in-kind relative to those that would occur under a fix-as-fails or advance maintenance regimen and provide some level of additional justification. Since a replacement-in-kind appears to be well justified in the current analysis and since this expectation would have little impact on the with-project alternatives, no specific assumptions or procedures were implemented to account for this phenomenon.

4. Identification of Alternative Improvement Plans

Several alternative improvement plans were considered to address problems and needs at Chickamauga Lock. These alternatives were limited to structural measures involving the construction of larger locks. Helper boat operations at Chickamauga and Watts Bar are implemented when justified in the project economic life. Other nonstructural measures were evaluated in the without-project condition analysis, but did not improve lock capacity.

a. Lock Replacement Alternatives. Without-project analyses considered replacement of the existing 60’x360’ lock with a lock of identical size (RIK). The with-project analyses of structural measures for Chickamauga considered replacement of the existing 60’x360’ lock with a new lock facility measuring, 75’x400’, 110’x600’ or 110’x800’. Table V-9 presents a brief summary of the lock replacement alternatives.

A lock measuring 110’x800’ would permit the simultaneous lockage of 12 jumbo barges, but would be larger than any of the other Tennessee River locks except Pickwick (110’x1000’) and the new Kentucky Lock (110’x1200’ under construction). The most common lock size on the Tennessee River downstream of Chickamauga is 110’x600’. A lock 110’x 600’ would accommodate nine jumbo barges in a single lockage, while providing compatibility with most of the other structures on the Tennessee. A 75’x400’ lock would be an intermediate lock size for the Tennessee River, unlike any existing lock except Melton Hill, on the Clinch River. A lock of this size would handle four jumbo barges in a single lockage, compared to one jumbo barge for the existing 60’x360’ lock.

Previous studies considered locating a new lock either on the landward or on the riverward side of the existing lock. A lock on the landward side would require substantial relocations and cause significant environmental impacts. The first concern is relocation of North Chickamauga Creek. Locating a suitable route for the stream would be difficult and there would be significant environmental impacts of such an action. Also, the railroad bridge downstream of the lock would require relocation to allow for construction of a new approach channel. Due to cost and potential environmental impacts, this location was eliminated.

On the riverward side, studies considered extending the lock chamber upstream from the spillway into the reservoir or constructing the lock chamber downstream of the spillway. Because of the previous investigations, the location selected for construction of a new lock was downstream of the spillway section, riverward, and adjacent to the existing lock. This was the only location that, for most lock sizes, precluded the need to relocate or alter the railroad bridge just downstream of the project and the highway bridge that crosses the dam. The existing highway bridge was constructed to provide a clear span adjacent to the existing lock, to provide for a new lock at this location.

Constructing the lock immediately downstream of the existing spillway eliminates the need for an upstream cofferdam during construction. The spillway gates would be removed once the new lock gates are in place. The upper lock sill would be located just downstream of the existing spillway and most of the existing dam would be left intact.

Table V-9 Description of Alternative Plans	
Alternative	**Description**
Congestion Fee with the WOPC	A congestion fee will be assessed for utilization of the RIK.
75’x400’ Lock	Construction of a new 75’x400’ lock riverward of the existing lock. The existing lock would continue in use during construction of the new lock, but would close upon project completion this lock could accommodate four jumbo barges. Only, Melton Hill Lock and Dam on the Clinch River is of the same dimensions on the Upper Tennessee system. Helper boat operations would be implemented when justified.
110’x600’ Lock	Construction of a new 110’x600’ lock riverward of the existing lock. The existing lock would continue in use during construction, but would close upon project completion. This lock would accommodate nine jumbo barges. This size matches most of the main Tennessee River locks. Helper boat operations would be implemented when justified.
110’x800’ Lock	Construction of a new 110’x800’ lock riverward of the existing lock. The existing lock would continue in use during construction, but would close upon project completion. A lock of this size would accommodate 12 jumbo barges. There are no other locks of this size on the Tennessee River. Helper boat operations would be implemented when justified.

Given the problem with AAR, a new lock downstream of the dam is considered the best means to preserve the structural integrity of the dam. Only a limited portion of the dam’s spillway will need to be removed. Locating the lock farther upstream would require a complete breach of the spillway thus increasing the potential for movement of the spillway sections adjacent to the new lock. Locating the lock downstream of the dam’s spillway also eliminates the possibility that AAR along the axis of the dam could apply added loading on the new lock wall.

Locating the new lock riverward of the existing lock places the downstream approach farther from the occasionally high velocities of the North Chickamauga Diversion Canal. The positioning of the cofferdam during construction of a new lock would necessitate widening and deepening the navigation channel downstream of the railroad bridge to improve the approach alignment to the existing lock. This would maintain traffic through the existing lock during new lock construction. Upon completion of a new lock, the existing facility would be closed with a concrete plug to ensure the project's water barrier.

The most obvious difference between the alternative lock sizes being considered is in the material quantities required for construction. A lock measuring 75’x400’ would be similar in terms of construction impacts and requirements to a RIK (60’x360’). A 110’ wide lock would require the removal of six gate bays during construction, with five removed permanently. By way of comparison, the smaller lock widths would require the removal of five gate bays during construction with four of those removed permanently.

Increasing the lock size to 110’x800’ would have a number of impacts beyond those encountered with the 110’x600’ structure. The power line downstream of the current lock location would have to be relocated. The cofferdam for the new lock would have to extend under the downstream railroad bridge. With this lock size, the cofferdam and railroad bridge would restrict the lower approach to the existing lock during construction. Tows would not be able to access the existing lock chamber during construction of the new lock and the railroad bridge would have to be relocated at a substantial cost.

b. Economics of the Alternative Plans. The following presents the preliminary economic analysis for each of the alternative plans. Costs and benefits are analyzed assuming a 50-year project life and a discount rate of 6.375 percent.

Contingencies are computed by individual item and are included in the first costs. Investment costs reflect the inclusion of interest during construction. The differences among the lock replacement alternatives are in the lock costs; planning, engineering, and design costs; and construction management costs. Other major cost categories are identical among the plans. The variations in lock costs primarily reflect differences in concrete requirements for the alternative lock sizes.

Investment costs represent the sum of the construction outlays plus the accrued interest on those expenditures up to the time that a plan’s benefit or service become available. The earliest probable date by which a new lock could become available for use at Chickamauga is 2010. Any of the lock size alternatives could be placed in operation by 2010, under an optimal authorization and implementation scenario. Therefore, 2010 became the base year for calculating interest during construction for each of the final alternatives. All expenditures prior to year 2010 were increased by adding compound interest at 6.375 percent from the date of the expenditure to year 2010. Similarly, expenditures after year 2010 were discounted from the date of expenditure to the base year.

A summary comparison of the alternative plans is displayed in Table V-10. Project data are displayed for the cost minimization framework. All of the plans produce positive net benefits. The 75’x400’ alternative lock size is the most economical of the lock sizes considered with annual net benefits of $16.1 million. The 110’x600’ alternative lock size is also economically viable with annual net benefits of $14.8 million. The least viable of the alternative lock sizes is the 110’x800’ lock. Because of its much weaker economic justification (net benefits of $12.5 million), the 110’x800’ lock is not considered further. The 75’x400’ lock is considered for further evaluation because of its higher net benefits. The 110’x600’ lock is considered for further evaluation because it is only about a 15% increase in cost over the 75’x400’ lock and because of its compatibility with existing downstream locks.

Table V-10 Summary of Screening Level Annual Costs, Benefits, and Net Benefits for Alternative Lock Sizes (Screening Level Analysis, 6.375% Discount Rate)

Item	WOPC 60'x360'	75'x400'	110'x600'	110'x800'
Construction Investment Cost	$ 17,682	$ 18,367	$ 20,025	$ 22,287
Non-Construction Costs:				
Helper Boats	3,175	1,474	1,453	1,453
Maintenance	2,601	2,601	2,586	2,586
Repair	179	183	183	183
Recreation	27	25	25	25
Transportation	312,447	297,348	297,067	297,103
Total Non-Construction Costs	$ 318,429	$ 301,631	$ 301,314	$ 301,350
Total Annual Costs	$ 336,111	$ 319,998	$ 321,339	$ 323,637
Net Annual Benefits		$ 16,113	$ 14,772	$ 12,474
Summary of Screening Level Annual Costs (Including Externalities), Benefits, and Net Benefits for Alternative Lock Sizes				
Construction Investment Cost	$ 17,682	$ 18,367	$ 20,025	$ 22,287
Non-Construction Costs:				
Helper Boats	3,175	1,474	1,453	1,453
Maintenance	2,601	2,601	2,586	2,586
Repair	179	183	183	183
External	740	559	546	563
Recreation	27	25	25	25
Transportation	312,447	297,348	297,067	297,103
Total Non-Construction Costs	$ 319,269	$302,190	$ 301,860	$ 301,913
Total Annual Costs	$ 336,851	$ 320,557	$ 321,885	$ 324,200
Net Annual Benefits		$ 16,294	$ 14,966	$ 12,651

5. Development of Final Plans

In the final phase of plan formulation, the remaining alternatives are refined, evaluated, and compared in detail. The environmental, cultural, social, and national and regional economic, aspects of each plan are given full consideration. The final plans include the without-project condition and two replacement lock sizes – 75'x400' and 110'x600'. Both plans include helper boats at Watts Bar Lock.

The *Principles and Guidelines* requires the analysis of a nonstructural with-project alternative to lock replacement in the form of a lock congestion fee. Congestion fees call for the management of traffic demand at a lock through the imposition of lockage fees. The fee is designed to influence the shipper with very marginal waterway savings to shift their traffic to an alternate overland mode, thereby reducing the amount of lock congestion and increasing the rate savings of the remaining shippers. The congestion fee alternative typically includes the use of helper boats at a lock, when justified.

Therefore, a congestion fee will be added to the RIK and compared to the two structural alternatives being considered in the final analysis.